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Groundwater Abstraction from Aquitard, Aquiclude and Thin Aquifer in Barind

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GROUNDWATER ABSTRACTION FROM AQUITARD, AQUICLUDE AND THIN AQUIFER IN BARIND

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ABSTRACT

Barind is the land where the quality of life is inextricably linked to the availability of water. We are trying to help the section of people of such area where water is considered only from the viewpoint of quantity; they do not have the scope to think from quality aspect for their survival. The scale of poverty level here is normally measured on the basis of per capita income; however, to give a better indication about the quality of life, the accessibility for food, education, health, safe drinking water, sanitation, medicine and social empowerment for decision-making should also be included in these figures. Moreover, availability of drinking water is one of the basic human rights, and therefore should not be considered as a privilege.

The presence of an aquifer is the prerequisite for the installation of any type of well. In certain areas of Barind tract there is no screenable aquifer. Hence, surface water of ponds and river is being used as the source of drinking water as well as the source of bathing of villagers and their domestic animals, cleaning of house hold utensils and also used as source to meet the needs for supplementary irrigation. There are also many areas where there is no source of surface water and a totally water-bearing strata (aquifer), an essential element for well construction, is absent. The nature and cause of concern are as follows: (a) no aquifer, sometimes only aquitard and aquiclude (b) very deep static water table say deeper than sixty feet- which leads to a twofold result- people in neighboring areas lead inhuman life style and suffer from water borne diseases of mainly skin and stomach. Academically we define:

Aquifer: *a formation, group of formation, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs***.**

Aquitard: *A geologic formation, group of formations, or part of formation through which virtually no water moves.*

Aquiclude: *A saturated, but poorly permeable bed, formation, or group of formations that does not yield water freely to a well or springs. However, an aquiclude may transmit appreciable water to or from adjacent aquifers. (Groundwater and wells of Johnson Division, USA, 1987)*

However, the dug wells are installed at a depth of around one hundred feet having absolutely no aquifer. The cement rings are being used as well casing. Practically these wells are installed within the aquitard and aquiclude zone. The lithological classifications of the encountered layers are of pure clay-to-clay loam. The discharge from these wells is very small say ranging from 1 to 4 liter per second. This discharge is meeting the need of household water supply pumping in the water tank located on the roof of second floor. The homestead gardening, nursery maintenance and supplementary irrigation to rice and wheat are also being observed.

In the recent past a new type of short well in respect of depth having very thin aquifer has been invented/introduced with a quite reasonable discharge say around three cusec equivalent to 84 liter per second. This is something unique invention, projecting the well screens of four numbers in upward direction along the wall of well casing. The shortest well of only 73 feet total well configuration depth produces 84 liter per second. This type of well number is presently around three hundred are working for irrigation successfully for the last ten to fifteen years. These are locally known as Inverted well and favored and preferred by the farmers. The continuous test pumping for ninety-two hours has been conducted to assess the hydrogeological parameter and sustainability of the encountered aquifer. In conclusion this type of well has been proved to be wonderfully successful.

Keywords

Aquifer, Aquitard, Aquiclude, Dug well, Recharge, Inverted well and Effective well diameter

INTRODUCTION

The Barind Tract is distinguished by hard red soils which are different from those in other parts of Bangladesh. The Tract extends over Rajshahi, Dinajpur, Rangpur, and Bogra Districts of Bangladesh and Maldah District of West Bengal of India. The Rajshahi Barind Tract is located between 24°23¢to 25°15¢ north and 88°2¢ to 88°57¢ east. The temperature varies between 44°C and 6°C; the climate is dry apart from the monsoon season from mid June to mid October. Annual rainfall varies between 1400 to 1700mm;an increase in annual rainfall appears to have occurred following the development of dry season irrigation and afforestation.

Figure 1 Map of Barind area

Barind is the land where life is written in water. We are trying to address the section of people of such area where water is considered only from the viewpoint of quantity; they do not have the scope to think from quality aspect for their survival on the earth. The scale of poverty level is normally measured on the basis of per capita income; in fact, it should also include the accessibility for food, education, health, safe drinking water, sanitation, medicine and social empowerment for decision making. Moreover, availability of drinking water is one of the basic human right should not be confused as privilege.

Normally any type of well either for drinking or irrigation purpose is installed in the aquifer and this is pre-requisite. In certain areas of Barind tract there is no screenable aquifer. Hence, surface water of ponds and river is used for source of drinking water as well as source of bathing of village people and also for cows and buffalos, cleaning of house hold utensils and also use as source to meet natural calls in addition to supplementary irrigation. There are also many areas where there is no source of surface water and also totally water-bearing strata (aquifer) is absent which is normally thought to be an essential elements for well construction. The nature and cause of concern are as follows: (a) no aquifer, sometimes only aquitard and aquiclude (b) very deep static water table say deeper than sixty feet (c) people lead inhuman life style and (d) people suffer from water borne disease mainly skin and stomach. Academically we define

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DUGWELL

The dug wells are installed at a depth of around one hundred feet depth having absolutely no aquifer. The cement rings are being used as well casing. Practically these wells are installed within the aquitard and aquiclude zone. The lithological classifications of the encountered layers are of pure clay-to-silty clay. The discharge from these wells is very small say ranging from 1 to 4 liter per second. This discharge is meeting the need of household water supply and homestead gardening, nursery maintenance and supplementary irrigation to paddy and wheat fields. People of this area is very poor category which includes the Tribal and Aboriginal live in this remote, difficult and depressed belt. These people are totally out of any developmental activities of the society.

There is no normal screenable aquifer which is pre-requisite for having a normal land tubewell (No.6) or Deep set Hand tubewell or Tara Pump. Local peoples sometimes installs the Dug well even there is no aquifer. We know when a strata contains water bearing formation is termed as aquifer but whenever any layer does not contain/bear water bearing formation termed as aquiclude or aquitard. As per out test book knowledge these aquiclude and aquitard are not considered as source of tubwell water even the source of Dugwell.

In some areas only farm-pond and dug well is the only source of water as the static water level is beyond the suction capacity of shallow tubewell or hand pump. In these areas the dug well may be used as an irrigation source. The depth and diameter of the well may be increased to get more water inside the well. The height of each ring may be decreased up to 6 inches instead of normal 1 ft and each ring will remain without joint to enhance flow of water into the well.

CASESTUDYOF DUGWELL

As to test case a dug well was constructed at 52 ft total depth. From ground level to 42 ft it is completely clay, after that only 10 ft of silly clay was encountered. After 52 drilling continued upto 110 ft all through is pure clay. Dug well was constructed within the aquitard. The static water level was 22¢-9²on 14th March, 1999. Pumping started at 10-35 AM and the well dried at 11-30 AM. The recovery record was maintained and found that it took 31 hours and 10 minutes to recover to its original position. The recovery is shown in a graph annex-1. The capacity of the used submersible tiny pump was around four litres per second. This dug well is mainly used for supplying of drinking water as well as nursery development. Having this result of this well gradually dug well installation has gain pace in the problematic area of the region. However, it is recommend to use six inches height rings instead of 1 ft and without cement joints, that will increase flow into the dug well.

LITHOLOGY OF OPEN DUGWELL

Shapahar Zone Office

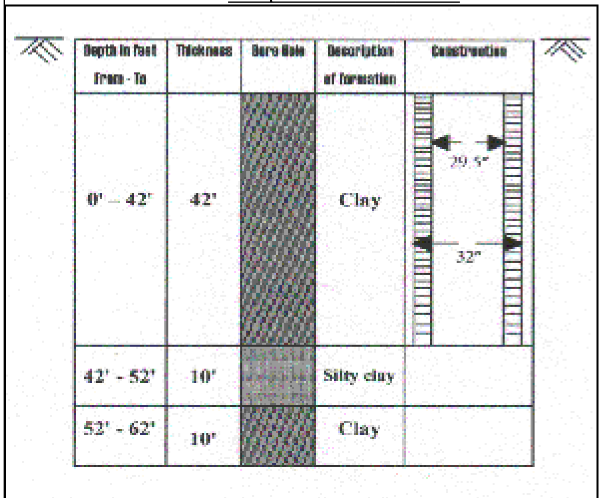

Figure 2 Dug well

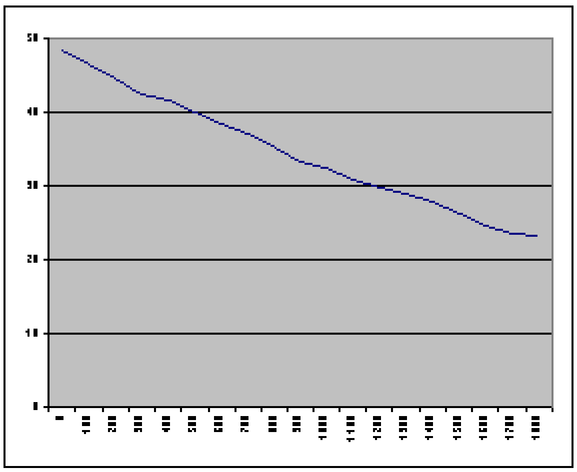

Figure 3 Dug well recovery

NATURE OF AQUIFER SYSTEM

An impression of the nature of the aquifer system can be gained from the geological cross-section of Figure 4. This diagram shows that the near surface clay layer is underlain by sandy horizons which may contain clay zones. There are extensive thick clays below the sandy aquifer zone.

The nature of the clay layer directly below the ground surface is important in assessing the possibility of movement of water from the ground surface into the underlying aquifer. The thickness of the clay varies from 2 to 20 m. Evidence from drilling suggests that the clay is not well consolidated since boreholes may collapse unless a temporary casing is installed quickly. Furthermore, it is possible to construct wells by hand digging through this overlying clay. This information indicates a classification as a poorly consolidated clay hence the effective vertical permeability may be as high as 0.01 m d^{-1}. There is no direct method of determining the effective vertical permeability of low permeability zones, therefore the above value is estimated from tabulated values in the literature and comparisons with other similar situations.

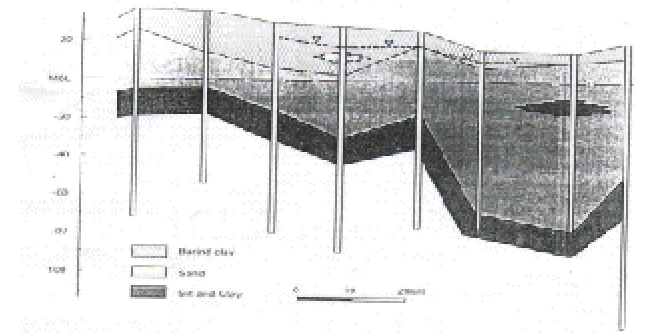

Figure 4 Geological cross-section AA: for location see Fig. 1

The geological cross-section of Figure 4 also shows that the sandy aquifer varies in thickness and that in some locations there are clay lenses or layer within the sand and sandy-gravel aquifers. In a review of 27 driller's logs, 11 were found to have intermediate clay layers with thickness varying from 2 to 6 m; unless these clay layers are continuous over large areas they are unlikely to have a significant impact on the effectiveness of the aquifer unit. The thickness of the sand or sand and gravel sequences vary from 18 to 80 m. This information suggests that the aquifer system, though shallow, should provide a reliable source of water provided that there is sufficient recharge and provided that the wells are designed to collect the water efficiently.

RECHARGE TO AQUIFER

Various attempts have been made to estimate recharge to the Barind aquifer. For example recent studies (EPC and Mott MacDonald, 1994) use a water level fluctuation method of analysis. This is an indirect method in which water table fluctuations are monitored; using as assumed specific yield estimates are made of the water entering the aquifer system. This approach is of limited reliability (*Lerner et al.*, 1990)

A direct approach using some form of water balance is more reliable. This often involves some form of soil moisture water balance (Rushton and Ward, 1979) but a soil moisture water balance is unlikely to be appropriate in the Barind area where almost 70% of the area is covered by rice fields which have puddled beds to minimize seepage losses. The extensive area of rice fields would appear to indicate that recharge to the Barind aquifer will be limited. However, a number of field observations indicate that recharge could be significant:

- there is little surface drainage in the Barind area suggesting that much of the precipitation infiltrates. Furthermore, during a site visit within two weeks of the end of the monsoon there was no evidence of damage due to any runoff following heavy monsoon rainfall.
- the bunds of the ricefields are high, often in the range 0.3 to 0.5 m; this suggests that the ricefields can store substantial quantities of water.
- however, two weeks after the end of the monsoon season the depth of water in most of the ricefields was small suggesting that much of the water had infiltrated into the aquifer.

· field studies and mathematical modelling by Walker and Rushton (1986) have shown that substantial quantities of water can pass through the bunds of ricefields into the underlying aquifer (the loss can be as high as 20 mmd-1when expressed as a depth of water).

From the above information it seems likely that much of the monsoon rainfall is collected in the ricefields and then infiltrates into the aquifer system. The rice fields are therefore a very efficient recharge system. Future studies should include simple lysimeter experiments (Walker and Rushton, 1986) in individual rice fields during the monsoon season to quantify those losses from the ricefields which become recharge.

APPROPRIATEWELLDESIGN

Field evidence suggests that in many locations the transmissivities are moderate to high which should allow pumping yields of up to 8000 m3 d-1 (3.3 cusecs). In order to make good use of the aquifer resources; appropriate technology is required for well construction. A specific example from Bogra (which is to the east of the study area) illustrates the development of an alternative well design for locations where conventional well design failed to produce an adequate yield. This discussion will use metric units, the imperial units in which the studies were carried out are listed in Table 1. The aquifer system has a 4.9 m layer of clay directly beneath the ground surface; this is underlain by 24.4 m of water-bearing strata consisting of fine sand, medium sand, coarse sand and gravel. Beneath the water-bearing strata is a thick clay which extends for a least 32 m.

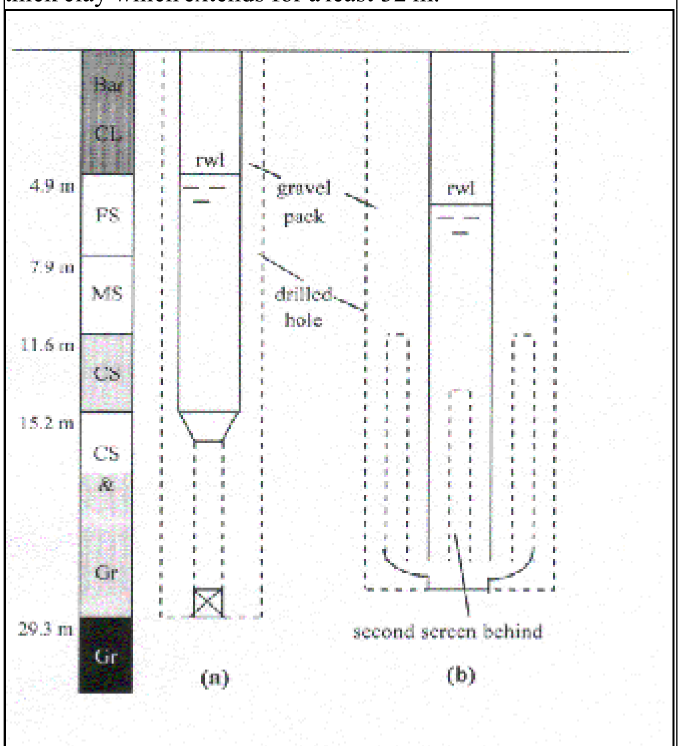

Figure 5
Comparison of conventional and inverted well designs; Bar Cl, Barind Clay; Fs, fine sand, MS, medium sand, CS, coarse sand, Gr, gravel: Cl, clay

Table 1
Comparison of single screen well and multiple inverted screen well; the original feet- second units are quoted with the equivalent metre-day units listed in brackets.

	Single screen	Multiple screen inverted
Lithology and Drilling		
Date of drilling	12.1.76	14.7.86
Thickness of upper clay	16 ft (4.88 m)	16 ft (4.88 m)
Thickness of water bearing strata	80 ft (24.4)	80 ft (24.4 m)
Total depth of well	96 ft (29.3 m)	96 ft (29.3 m)
Drilled diameter	20 in (051)	40 in (1.02 m)
Well Construction		
Length of solid casing	50 ft (15.2 m)	74 ft (22.6 m)
Diameter of solid casing	14 in (0.36 m)	14 in (0.36 m)
Length of screen	30 ft (9.1 m)	2×30 ft (9.1 m) 2×20 ft (6.1 m)
Diameter of screen	8 in (0.20 m)	6 in (0.15 m)
Lowest possible pumping level	44 ft (13.4 m)	68 ft (20.7 m)
Approx. gravel pack volume	115 ft^3 (3.3 m^3)	735 ft^3 (20.8 m^3)
Pumping Test Rest water level	15.6 ft (4.8 m)	21.5 ft (6.6 m)
Pumped discharge	1 cusec (2447 $m^3 d^{-1}$)	3 cusec (7340 $m^3 d^{-1}$)
Pumped water level	40.0 ft (12.2 m)	46.6 ft (14.2 m)
Pumped drawdown	24.4 ft (7.44 m)	25.1 ft (7.65 m)
Specific capacity	0.041 cusec ft^{-1} (330 $m^3 d^{-1} m^{-1}$)	0.120 cusec ft^{-1} (960 $m^3 d^{-1} m^{-1}$)
Average entrance velocity	(0.016 ft.s^{-1}) (0.0049 m s^{-1})	0.019 ft.s^{-1} (0.0058 ms^{-1})

For the initial well design in 1976, a solid casing was installed extending for 15.2 m with a further 9.1 m of 0.20 m diameter slotted screen, Figure 5(a). The rest water level is at a depth of 4.8 m; to allow a sufficient depth of water over the pump (which is situated towards the bottom of the solid casing) the lowest safe pumping level is 13.4 m. Consequently, the pumped drawdown cannot exceed 8.6 m. In a pumping test with an abstraction rate of 2447 m3 d-1 (1 cusec) the pumped drawdown was 7.44 m which is equivalent to a specific capacity of 330 m3 d-1. This yield of 2447 m3 d-1 (1 cusec) is marginal when water is to be used by a number of farmers.

In 1986 a new well was constructed within 30 m of the first well; the aim of this new well was to provide an increased yield. The new borehole was drilled at 1.02 m diameter; this is more than double the diameter of the original borehole. The solid casing in this new well extends for 22.6 m and there are four screens of 0.15 m diameter projecting upwards from the base of the solid casing, see Figure 5 (b). The hole is backfilled with pea gravel so that the volume of gravel pack associated with this borehole is approximately 20.8 m3 compared to 3.3 m3 for the original design. Even though the rest water level during the test was 1.8 m lower than for the original test, the yield was three times the original value at 7340 m3 d-1 (3 cusecs).

REASONS FOR THE INCREASED YIELD INCLUDE:

· the screen area is increased from 5.8 m2 to 14.6 m2 hence the entry velocities are similar; for the original well the entry velocity was 0.0049 m S-1 and for the replacement well 0.008 m s-1. These values are sufficiently small for there to be no significant head losses as water flows through the screen

· a greater pumped drawdown was possible; even though the rest water level for the second test was 1.8 m lower, the greater length of solid casing allows the pump to be set up to 7.3 m lower hence the maximum possible drawdown is increased,

· doubling the effective well radius which results from a doubling of the drilled diameter and the significant increase in the volume of the gravel pack ensures that the borehole is more effective at attracting water.

The increase in the yield of the well is remarkable, with the specific capacity for the inverted well screen 2.9 times the original design. The points raised above give qualitative reasons for this increase in specific capacity. A separate study using detailed pumped and recovery data is under way to give clear quantitative arguments for this improvement. For the example quoted above, the rest water table is close to or below the clay so that the aquifer response is unconfined. Where the groundwater head is clearly within the overlying clay layer, such that confined conditions apply, the improvement in yield is often substantially less.

A threefold increase in yield in unusual. Replacement wells using inverted screen have been installed in about 250 locations. In a review of a number of other cases, improvements in the specific yield have been between zero and 75%, with most of the improvements in the range 40 to 70%. Nevertheless, there are some instances when there is little improvement in the specific yield; this probably occurs because the critical feature is the ability of the aquifer to supply water rather than the ability of the well to abstract the water.

INSIGHTS FROM OBSERVATION WELL HYDROGRAPHS

Much can be learnt about the response of an aquifer system from observation well hydrographs. Figure 6 contains a typical hydrograph for observation well RS-41 in Nachol Thana. The construction of the well is for a solid casing through the clay layer connected to an open section of 1.8 m. Monthly readings of water levels are plotted; they show that prior to 1987 there was a relatively uniform seasonal fluctuation with the largest pre-monsoon depth to water of about 14 m and a recovery following the monsoon to depths of 10 to 8 m. In fact there is a general upward trend in maximum water levels, this may occur as a result of increases in recharge resulting from increases in monsoon rainfall.

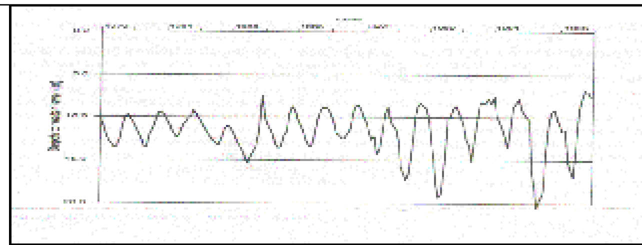

Figure 6 Hydrograph for observation well RS-41

In late 1987 three production wells started operating in the vicinity of RS-41; one production well is at a distance of about 0.25 km whilst for the other two the distance is about 0.5 km. The effect of these production wells is shown by deeper water levels in the observation well for most years from 1987 onwards. Water levels are almost five metres lower, demonstrating that the influence of the production wells extends for up to 0.5 km. The remarkable feature of the hydrographs is that the recovery following the monsoon is unaffected by the pumping. This is a clear demonstration that there is ample recharge to refill the aquifer following abstraction for irrigation purposes.

Hydrographs are available for a significant number of observation wells. From a examination of over 30 hydrographs none show trends of declining levels which would indicate incomplete recovery. This suggests that the aquifer is not being over-exploited.

DISCUSSION AND CONCLUSIONS

This account of the development of groundwater in Barind has shown that, despite the initial discouraging assessments of resource availability, successful development has occurred. The probable reason for the initial negative judgements is that hydrogeologists were looking for 'good aquifers', by which they meant geological strata continuous over considerable distances which are able to transmit large volumes of water. However, other strata, which consist of layers or zones of aquifers and aquitards, can provide a good source of groundwater. This is especially true when these mixed systems are recharged efficiently.

The Barind aquifer is a good example of steady development over many years in which a trial and error approach is used. Considerable effort has been expended in developing tubewells which can exploit these relatively thin aquifers. For some locations the traditional well construction. Of a solid housing containing the submersible pump with a slotted casing beneath, provides an adequate yield. For other locations the yield of the traditional deep tubewell is unsatisfactory. This occurs because the conventional design restricts the maximum pumped drawdown; the inverted well technique allows larger pumped drawdowns and also increases the open area of the slotted casing. Although there has been a steady increase in the number of deep tubewells, careful monitoring of a large number of observation wells has shown that no over-exploitation has occurred. An important factor in avoiding over-exploitation is the efficient recharge mechanisms through the extensive rice fields.

Plausible reasons for the good tubewell yields have been developed but more detailed fieldwork is needed to confirm features such as the nature of the overlying clay and the long term reliability of the inverted wells. In addition, studies are required of the overall water balance with special emphasis on runoff and quantifying the recharge through the bunds of rice fields.

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